# WAR WOUNDS OF THE EXTREMITIES*

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FROM a medico-military point of view, wounds of the extremities are of great significance. This is true primarily because they constitute 65 to 70 per cent of all wounds seen in Army Hospitals in combat areas. In this connection, it is interesting to note that the incidence of wounds of the extremities in the Civil War was 70.8 per cent; in World War I, 76.4 per cent; and thus far in World War II, 73 per cent. Although the incidence of wounds of the extremities in these wars are nearly identical, in World War II such injuries, especially to the lower extremities, are usually more severe. This is due in part to the more violent explosives used in this conflict, but it is particularly due to the widely used land mine which causes extensive damage when exploded by the tread of the soldier's foot. The extremity is literally pulpified by the terrific explosion and can often be treated only by amputation. It is not uncommon to see patients with both lower extremities seriously damaged. The fact that a wounded man constitutes much more of a hindrance to an army than a dead one further emphasizes the military significance of these wounds. Wounds of the extremities will be discussed under the headings (1) soft tissues, (2) blood vessels, (3) nerves, (4) bones and joints, and (5) wound infection.

## SOFT TISSUES

While the fundamental principles of treatment of war wounds are identical with those of all wounds, certain conditions in war preclude the use of some surgical measures and necessitate modification of certain others. All surgeons who have had experience in this war subscribe to the basic principle of thorough debridement of wounds. The proper performance of this procedure is the most important step in the treatment of war wounds, certain reports to the contrary notwithstanding. The heavier the contamination of the soil of the battlefield, the more important adequate debridement becomes. On the other hand, wounds occurring in a relatively clean environment, such as on shipboard or in airplanes, may require less extensive debridement. In civil life, the surgeon can spend as much time as is required to do the most thorough and meticulous wound revision. When the press of work is not great, the military surgeon can do likewise; however, when casualties are heavy and the litter cases accumulate outside the operating room, the dictum of the "greatest good for the greatest number" demands a more expedient but perhaps less ideal debridement. Having accomplished this important fundamental in the surgical care of a wound in the most approved manner, the civilian surgeon frequently closes the wound by primary suture, because he has operated within the short time following injury, has had access to a well appointed operating room with adequate assistance, and can keep his patient in one hospital for close supervision by him and his staff for as long as is necessary. Under such circumstances, primary closure is proper. Consider the situation confronting the military surgeon who, even under the best conditions, sees his patients several hours after wounding and frequently not until many hours have elapsed since the injury was received; all wounds are contaminated; the operating room, though well equipped with instruments, may be in a tent or in an improvised shelter; and the patient, except in unusual instances, will not remain long under supervision in the forward hospital, since, in order to make room for incoming casualties and to maintain mobility of such forward installations, he must be evacuated promptly to a hospital farther back. The dangers of primary closure under these circumstances are obvious and the principle of leaving *all* war wounds open after debridement is sound and proper. Although a certain percentage of war wounds can be closed successfully by primary suture, the large number of disastrous complications which will and do ensue after routine closure of these wounds make it imperative to follow the rule of "no primary closure of war wounds;" and yet this principle of war surgery is too often not applied by surgeons recently arrived in battle areas, and they have to observe the disastrous results following primary closure to be convinced of their errors in judgment.

Certain facts concerning debridement have been learned from the experiences of this war and deserve emphasis. Tissue damage is frequently more extensive than is apparent on the surface and, although the wound looks innocent from the outside, there may be considerable shattering and destruction of tissues in its depths. For this reason, all wounds must be thoroughly explored. This means adequate incisions in skin and fascial planes in order that access may be had to all parts of the wound. It does not mean over-excision of skin, which is a common fault in technique. When a wound is thus explored, it is common to find beneath the small wound of entrance, foreign bodies, bits of clothing, hematomas, devitalized muscle, and not infrequently, damage to a major vessel. All devitalized and soiled tissue having been excised, hemostasis is effected, and vaseline gauze dressings are laid loosely in the wound.

*The subject "War Wounds of the Extremities" was presented by a representative of the Medical Corps, United States Army, at each of the twenty-one War Sessions of the American College of Surgeons which were held in February, March, and April, 1944. The names of these representatives and the War Sessions in which they participated are given on page 78 of this BULLETIN.

Tight packing of a wound is comparable to primary closure and must be avoided for this reason as well as on account of its "tourniquet effect." It has been found wise to splint the part even in the absence of fractures.

### BLOOD VESSELS

Peripheral vascular injuries, especially those involving major vessels, are particularly significant complications of wounds of the extremities and occur much more frequently than is commonly realized. This is shown by the fact that in one of the vascular centers the number of operations now done for traumatic aneurysm averages about twelve per month. Various forms of injuries may occur, including laceration of the vessel, partial or complete severance, thrombosis, acute reflex vasospasm, false aneurysm, and the subsequent development of arteriovenous aneurysm. It is important to recognize that the vasospasm is a natural response to those forms of trauma which directly or indirectly affect vascular structures, and it is therefore a common occurrence in most of these injuries. Depending upon a number of factors, it may involve only a small part of the vessel, may spread to neighboring vessels of the entire extremity, or may be generalized to involve even larger areas of the body. Although it may be considered a compensatory mechanism under certain conditions, if continued it may lead to undesirable and hazardous consequences. In cases in which the actual traumatism to the tissues has already seriously impaired their vitality, this vasospasm may be the deciding factor upon which the life of the limb depends. An additional consideration is the fact that, in some cases, the resultant ischemia may be a contributing factor in the development of gas bacillus infection.

In cases in which there is direct injury to major vessels with laceration, partial or complete severance, or thrombosis, ligation will usually be necessary. The repair of these injured vessels in such a way as to maintain blood flow through them is rarely feasible because of the conditions under which they occur and must be handled, and because of the character of the injury. Cleanly incised longitudinal wounds which may be most successfully sutured, or even incised transverse wounds which may be repaired by end-to-end anastomosis or preferably by non-suture tube techniques are only occasionally observed in war injuries. For these reasons, the more practical and realistic procedure of ligation must usually be employed. This should be done not by ligation in continuity but by placing non-absorbable ligatures well above and below the site of injury with excision of the intervening damaged segment in order to eliminate the dangers of secondary hemorrhage, thrombosis and vasoconstrictor influences. Other cases with thrombosis should be similarly ligated following excision of the thrombosed segment. These cases must be distinguished from localized segmental spasm of the artery. In cases manifesting this phenomenon, the limb is cold, pale, and pulseless but evidence of hemorrhage or hematoma indicating that the vessel has been lacerated may not be present. This type of reflex vasospasm has appeared in cases in which the site of the trauma was remote from the vessels. Thus, a case has been observed in which a shell fragment produced a wound of entrance and exit on the lateral aspect of the right calf at its midpoint. Although at operation the wound track was found to be from 5 to 8 cm. from the posterior tibial artery, complete spasm of this vessel was observed. In some cases in which the wound was immediately adjacent to the vessel, which revealed no grossly visible injury, the artery has been found in complete spasm. Still other cases have been observed in which spasm has developed following minimal manipulation of a simple fracture. The degree of vasospasm varies considerably from localized constriction with consequent minimal ischemia to a more extensive and generalized involvement, especially of the collateral circulation, with sufficient ischemia to produce actual gangrene. Moreover, the vasospasm may persist for periods as long as or even longer than 48 to 72 hours.

Rational treatment in these cases is directed toward counteracting vasospasm and producing maximum vasodilatation in the involved extremity. Since the disturbance is apparently due to the development of a vasomotor reflex initiated in the traumatized tissues, and since vasoconstrictor impulses are transmitted by way of the sympathetic nerve fibers, interruption of these impulses in the circuit prevents vasospasm and permits vasodilatation. This interruption may be accomplished by debridement of surrounding traumatized tissue, periarterial sympathectomy, or procaine hydrochloride block of the regional sympathetic ganglia. The last procedure is considered the most effective method of producing maximum vasodilatation in these cases and should be employed in all types of peripheral vascular injuries accompanied by manifestations of vasospasm. It may be necessary to repeat the sympathetic block at least once or twice daily for several days. Close observation is essential in cases with injury of the major peripheral vessels and, for this reason, these patients should be evacuated as soon as possible after injury to installations with facilities for the proper surgical care described above. They should not be moved from these installations and should not have plaster-of-Paris cast applied until the danger of ischemia is past. Three vascular centers have been established in General Hospitals in the United States for the specialized treatment required in the management of serious problems and complications, such as traumatic aneurysms, associated with peripheral vascular injury and disease. All cases of this nature are sent to these centers, which are especially staffed and equipped for this purpose.

### NERVE TRUNKS

Injury to major nerve trunks occurs in from 12 to 15 per cent of all extremity wounds in this war. The relative frequency, the protracted management, the

crippling effects, and the not too satisfactory results of treatment of these injuries emphasize their importance. The possibility of this complication should always be considered and efforts directed toward early diagnosis in order to facilitate proper evacuation and the necessary early treatment. While it is recognized that under war conditions primary anastomosis of severed peripheral nerves is not generally feasible, it should be attempted if the nerve ends are readily accessible and can be approximated without tension. This should be done as an end-to-end anastomosis with the ends to be united cut at exactly right angles with a sharp scalpel. During the suture, axial rotation should be avoided. Fine silk or tantalum wire sutures should be employed and the ends of the nerve coapted by simultaneously pulling taut all the sutures which have been passed through the epineurium only of both stumps. If primary anastomosis is not possible, the injured nerve ends should be identified and a sling suture of fine stainless steel wire placed between them, or they should be anchored with similar suture material to the surrounding tissue in order to prevent retraction. Metal suture material is advocated here because it facilitates roentgenographic identification preceding subsequent repair. In order to minimize the irreparable degenerative changes that occur in the end-plates of severed nerves, early repair of those nerves is essential. For this reason, every effort is made to evacuate these patients as soon as possible to the neurosurgical centers in General Hospitals in the United States where operative repair and the necessary postoperative physiotherapy can be instituted. At present, 18 neurosurgical centers are strategically located, equipped, and staffed to provide the best treatment available for these cases. Recent experience has shown that operative repair can be done within a week to 10 days after the wound has healed, which is much earlier than was formerly thought possible. This is particularly desirable since the earlier the operation can be done, the better the end result is likely to be. The use of tantalum wire for suture material and tantalum foil for wrapping the anastomosed nerve end is considered especially valuable because this metal element is relatively inert and therefore produces minimal tissue reaction and protects against intraneural and invading scar tissue formation. Recent experience with the use of fibrin film suggests that it may be more valuable for this purpose. Because of the protracted recovery period in these cases, careful postoperative care and follow-up observations are essential in their proper management and study. A program of this nature permitting prolonged observation has been instituted in the neurosurgical centers.

### BONES AND JOINTS

Bone and joint involvements in wounds of the extremities are among the most important complications because of the protracted hospitalization and disabilities which they cause especially if early treatment has been inadequate. The difficulties in the ideal management of these cases are greatly increased under war conditions. Moreover, the highly destructive, shattering fractures with great loss of bone substances commonly observed in such cases emphasize further the problems encountered in their treatment. For these reasons, efforts have been directed toward prompt and proper management along principles which, under war conditions, have given the most satisfactory end results. In the forward echelons the essential problem in the management of wounds of the extremities is concerned principally with the most expedient and comfortable method of immobilization during evacuation. It must provide adequate fixation for ambulance or jeep transport over rough roads and, at the same time, assurance that circulation of the extremities will not be jeopardized or that additional soft part injury will not be incurred. For fractures of the femur about the knee and both bones of the leg above the ankle, these desiderata are best met by the use of the Army half-ring splints with the litter bar, ankle strap, and five triangular bandages. Traction is effected for a short period of time by the ankle strap or hitch about the ankle with the shoe on, but prolonged use of this method is dangerous as it produces skin necrosis. Skin traction with the shoe off is much safer, and this method has been found the most satisfactory for evacuating these cases from the first and second echelons to the Evacuation Hospital or even to the General Hospital. Skeletal fixation and skeletal traction in patients who are to be transported have resulted in much discomfort and in bone infection in the pin wounds. These procedures may rarely be used in the management of these cases in the forward echelons when skin traction cannot be used because of destruction of skin by burns or trauma. Following adequate debridement in the Evacuation Hospital, patients with fractures of the shaft of the femur or tibia and fractures involving the hip or knee joints are evacuated to the General Hospitals in the Army half-ring splint with skin or skeletal traction or in a padded plaster spica. In this connection, the so-called "Tobruk" splint has received favorable comment and is applied as follows: by means of traction, preferably skin traction, the extremity is pulled down, a plaster cast is applied over the traction to the thigh and leg, a half-ring splint is applied to which the traction is made fast, the extremity and splint are wrapped by several turns of plaster, and the cast is completely split. Padded posterior and lateral wire ladder splints are considered best for evacuating patients with fractures of the ankle and foot. In transporting patients with fractures of the humerus from the forward echelons to the first hospital installation such as the Evacuation Hospital, the Thomas arm hinged splint with skin traction or the immobilization of the arm to the side of the chest with a sling or Velpeau bandage incorporating a padded external splint have been found satisfactory. For evacuation from this hospital to one further to the rear such as the General Hospital, the best method consists of a U-shaped

moulded plaster splint extending from the axilla around the elbow and up the outer surface of the arm and shoulder to the neck, supported by bandages and a sling. For fractures of the elbow and upper third of the forearm, immobilization is best effected with the elbow flexed by the use of a posterior wire ladder or moulded plaster splint extending beyond the wrist and supported by a sling.

In the management of compound fractures in forward echelons, adequate debridement is imperative and the principles described above are followed. Whereas internal metallic fixation is at times a valuable procedure in the definitive treatment of simple fractures, its application in the emergency surgical treatment in these echelons is followed by frequent complications and failures. For these reasons, the more conservative principles of careful debridement are advocated—leaving the wound open and covering it with loosely placed fine mesh vaseline gauze, followed by cast or splinting with skin traction. The importance of properly padding and completely bivalving all casts of the extremities prior to evacuation is emphasized.

Penetrating wounds of the joints are also treated by adequate debridement, removal of all loose bone fragments, irrigation of the joint cavity, and closure of the synovial membrane. The soft tissue wound down to the sutured synovial membrane is left open and is covered with loosely placed gauze. Immobilization is obtained as previously described.

Because of the highly destructive and shattering injuries incurred in this war, particularly from land mines, cases requiring amputation have been relatively frequent. In the performance of amputations under war conditions, there has been an unfortunate lack of familiarity with the principles of open amputation. The most common errors of judgment have been concerned with unnecessary sacrifice of tissue and with closure of the stump resulting in osteomyelitis, gas gangrene, or other serious infections, or with a resulting stump that is too short for satisfactory prosthetic fitting. All emergency amputations for trauma or infection should be performed at the lowest level possible which permits removal of all devitalized and contaminated tissue regardless of stump length. Revision of the stump in accordance with prosthetic considerations may be subsequently performed. The open (guillotine) circular method, with severance of successive layers at the level of retraction of the preceding layers is the procedure of choice, and it should be kept in mind that skin should not be needlessly sacrificed in order to give a neat stump. The wound must be left open and a vaseline dressing used. Skin traction to the stump must always be immediately applied following the amputation and must be continued until healing occurs. The short flap-type open amputation may be done only in cases in which early evacuation is not contemplated and subsequent closure at the same installation is deemed possible, such as in a General Hospital. As early as practicable after the primary amputation, all major amputees are sent to General Hospitals designated as amputation centers for revision of stump or fitting of prosthesis. Before discharge from the Army, these patients are fitted with a proper prosthesis and taught how to use it and how otherwise to care for themselves.

### WOUND INFECTIONS

All war wounds may be considered contaminated. The degree of infection varies from minimal surface involvement to actual invasive infection with regional or generalized extension. Whereas the frequency cannot be estimated accurately, the incidence of serious infection, it is believed, has not been high. The prevention and treatment of these infections consist in the application of well-established principles which have been repeatedly emphasized. In this connection, the exact status of chemotherapy has not been completely established. It may be justifiably stated, however, that in the sobering light of recent critical studies and more extensive experience the widely heralded and perhaps overenthusiastic concept regarding the value of the sulfonamides in wound infection, which was expressed earlier in the war, must now be considerably modified. Whereas many surgeons continue to frost the wound with sulfanilamide, the beneficial effects of the drug, when applied locally, are questioned by careful observers. The critical surgeon, in our Army and in the British Army, is beginning to veer away from the local use of the sulfonamides and to rely on their systemic effect to prevent general sepsis and spreading infection. For this reason, it is recommended that sulfadiazine, which is considered the drug of choice, be administered by oral or parenteral means at the earliest opportunity after injury and continued postoperatively. At present, penicillin appears to be the most promising bacteriostatic agent in the control of wound infection and seems to have great potentialities in military surgery. The immunization program with tetanus toxoid and the routine administration of a stimulating or "booster" dose immediately after wounding have effectively controlled the occurrence of tetanus in the United States Army. No case of tetanus has occurred in American soldiers who have been properly immunized and have received these tetanus toxoid injections.

The most serious infection and the one which continues to be a grave problem is gas gangrene. Indeed, the general incidence of gas gangrene thus far in this war closely approximates that of the last war. On the basis of extensive studies of anaerobic infections of war wounds mong the British troops in the Middle East, MacLennon found that "neither in prevention nor treatment has much advance been made in the last 25 years" despite the fact that in this period "the potency of antisera has at least been doubled and the whole group of sulfonamide drugs introduced." Similarly, the incidence and mortality of gas gangrene among our wounded have been in accord with these findings. These startling observations serve to emphasize the importance of this

problem especially in view of the increased possibilities of anaerobic infection as fighting on the highly fertilized soil of the European Continent progresses. Since the mortality (40 to 50 per cent) and the morbidity in established gas gangrene are so high, the prevention of this complication is of the greatest importance. Effective prophylaxis depends upon an adequate realization of the factors and conditions under which the disease is particularly liable to develop. Since the underlying factor contributing to the development of this grave infection is the presence of anaerobic environment and spore-bearing bacilli of the Clostridium group and of devitalized tissue, preventive measures should be designed toward the removal of all tissue in which the circulation is lost or dangerously impaired, the avoidance of procedures that jeopardize the vascularity of the affected part, such as unpadded, unsplit casts, tight plugging of wounds, circular bandages, and tourniquets, and the provision for adequate drainage of the wound. The prophylactic value of polyvalent gas gangrene antitoxin has not been established clinically, and its use is not recommended. The treatment of established gas gangrene is directed toward controlling the infection and combatting the toxemia. This is best accomplished by the combined use of surgery, antitoxin, sulfonamides, penicillin, and supportive measures.